Accelerated Weathering

Its Use for Routine Testing of Paints

New Jersey Zinc

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160 Front Street, New York

Accelerated Weathering

Its Use for Routine Testing of Paints

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Accelerated Weathering

Its Use for Routine Testing of Paints

The ultimate criterion of quality and economic value of a coating material is the service rendered under the conditions for which it is designed. The prophesying of such service, through controlled laboratory tests, frequently plays a major part in maintaining uniformity in production, and especially in designating the procedure to be followed in development work. Some service conditions are so very simple, involving only one or two deteriorating factors, as heat or resistance to certain chemicals, that they can easily be reproduced in the laboratory. More often, they are very complicated, made up of numerous deteriorating factors, changing in intensity from time to time. Thus, weathering, as associated with the effects of climate, represents probably the most complex of service conditions.

Although exposures under the actual conditions in question can be resorted to for test purposes, in most cases this is far too slow and results in a continual demand for test methods that will prophesy service in a comparatively short period of time. The development of such tests has been along two distinct lines. The one is concerned with measuring some one physical property of the finish and interpreting it as an indicator of durability. Various distensibility measurements, whether they be by means of a stress strain machine, bend tests, or the kauri reduction tests, are examples of this method. The difficulty with such practice is to evaluate the degree to which the physical measurement is an actual indicator of possible service. The other direction of development has been toward duplicating in the laboratory an intensified arrangement of the deteriorating factors. Accelerated weathering is the best known example along this line.

The simulation of climate in a laboratory test method presents a very complex picture, when one considers the varieties of climate, its variation in the same location from year to year, and the difficulty of accepting any one variation as a standard. In addition, accelerated weather testing has come to include durability determinations for gaseous industrial locations, and even severe interior exposures. Hence, it is reasonable to expect that the problem must be carefully studied from a theoretical and fundamental angle before a completely satisfactory test method can be evolved. According to published literature, con-

siderable research work has been done, but much ground still remains to be covered.

Accelerated weathering has been a subject of intensive research in this laboratory for a number of years. Naturally, in a subject with such wide ramifications there will be considerable variation in the ways different paint laboratories put the available fundamental information to practical use. This bulletin concerns itself primarily with the present application of accelerated weathering as a routine test method in this laboratory without any consideration of arguments for or against the use of any specified equipment or test cycle.

The equipment has been designed to permit flexibility in use and a ready adaptation of any further development in the fundamental knowledge. The system as it is described has been in use for approximately two years, a sufficient length of time to prove its worth in its present stage as a routine test medium. With its aid, the quality of a coating can be established as good, bad, intermediate, etc., or evaluated in terms of a reference material whose characteristics have become known through long usage in actual service. As will be explained later, for the present it is better to designate durability in relative terms than by any definite period of time.

Some Fundamental Considerations of the Test Method

The mechanical aspect of the application of any test method will naturally be shaped by its theoretical and fundamental considerations. A brief summary of these, as worked out in this laboratory,[1] will facilitate an understanding of the apparatus and the routine procedure.

The deteriorating agents of weather, regardless of location, may be grouped under three general headings: sunlight, moisture and temperature. Sunlight is a very variable factor, whose effects are but poorly understood. Moisture may act as a vapor, resulting in high and low humidity conditions, as a liquid in rain or fog, or as a solid in snow. Temperature may cover warm or cold, including freezing, variations within these designations, or severe changes from one extreme to the other. The most prevalent natural weathering combination may be summarized as sunlight with low or high humidity, and at low or high

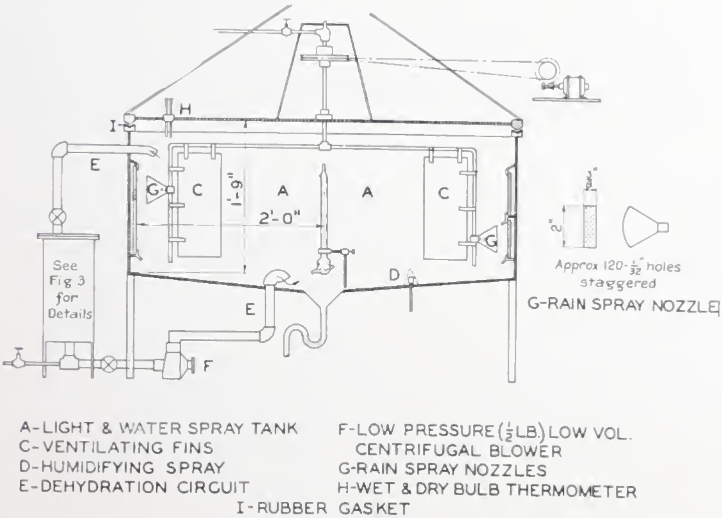


Figure 1
Single Compartment Exposure Unit.

[1] H. A. Nelson—"Accelerated Weathering of Paints on Wood and Metal Surfaces," Proceedings, Am. Soc. Test. Mats., Vol. 22, Part II, 1922.
H. A. Nelson and F. C. Schmutz—"Further Study of Accelerated Weathering: Effect of Variations in Exposure Cycle Combinations on Common Types of Varnishes," Proceedings of the Am. Soc. Test. Mats., Vol. 24, Part II, 1924.
H. A. Nelson, F. C. Schmutz and D. L. Gamble—"Accelerated Weathering: Further Development of Apparatus and Exposure Cycles," Proceedings, Am. Soc. Test. Mats., Vol. 26, Part II, 1926.
H. A. Nelson and F. C. Schmutz, "Accelerated Weathering: A Consideration of Some Fundaments Governing its Application," Ind. and Eng. Chem., Vol. 18, p. 1222, 1926.

FIGURE 7
Single Compartment Exposure Unit

temperatures, or changing temperatures. These weathering agents bring about disintegration by activating changes, individually or collectively, along three distinct lines: (1) oxidation; (2) reactions within the coating material, as the deterioration of nitrocellulose under heat,[3] and (3) physical changes, as the stresses and strains induced by freezing. Oxygen as a constituent of air and erosion as exemplified by wind borne sand, etc., are the other major deteriorating agents not included in the previous analysis of climate. The former will be referred to later in this bulletin. Because of the ever-changing character of erosion at any one place and the rather meager information at hand covering its effects, this factor is being omitted from consideration for the present.

Since the necessity for reasonable simplicity limits the extent to which the infinite variation of weather can be simulated in a routine test method, only the following conditions are included in this system:

1. Sunlight at an elevated temperature (120°–130° F.) and low or high humidity.
2. Rain alone.
3. Low temperature or freezing (20°–25° F.)

[3] [illegible] "The Stability of Nitrocellulose," Paint, Oil and Chemical Review, [illegible]

Apparatus

The mechanical development of accelerated weathering has been along two distinct lines, the one, the wheel or revolving drum type, and the other, the closed tank variety, as used in this laboratory. A wide leeway is permitted in the construction of the closed tank type to suit the individual conditions. Figures Nos. 1 and 2 illustrate a simple unit which will accommodate 25 panels, 6 x 12 inches. The panels must be transferred by hand for the refrigeration exposure periods. To overcome such handling and, also, to make the changes more instantaneous and thus more effective, the combination equipment illustrated in Figures Nos. 3 and 4 is used. This apparatus will take care of 50 panels, 6 x 12 inches. Naturally, reducing the size of the panels, if permissible, will considerably increase the actual test capacities of these units.

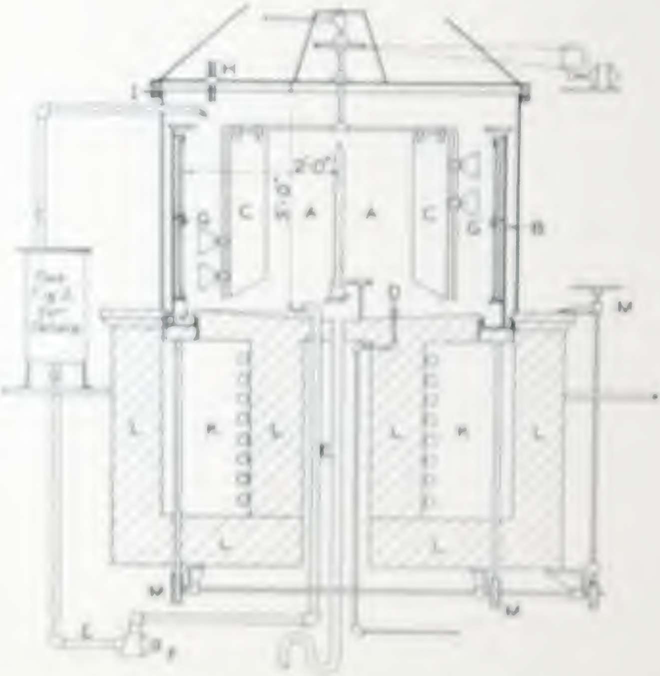
Light and Water Exposure Tank

The essential features of both arrangements are the same. A circular tank "A," Figures Nos. 1 and 3, with a readily removable cover, constitutes the light and water spray chamber. The test surfaces are two feet from the light source. In the combination unit the panels are fastened to an inner movable drum ("B," Figure No. 3) instead of the wall of the light tank. Air circulation is maintained by means of revolving fins, "C," Figures Nos. 1 and 3. Radiation from the walls is relied upon to dispensate the excess heat generated by the light, and quite a close constant temperature can be maintained by varying the speed of revolution of the fins. A tank temperature of 130° to 140° F. has been adopted as standard for all light exposures.

Humidity Control

High humidity is developed by atomizing warm water in the tank. ("D," Figures Nos. 1 and 3.) A Schutte and Koerting (Philadelphia, Pa.) ¾ mm. brass nozzle serves very well for this purpose. It is advisable to cap the atomizer with a fine mesh copper screen to further break up the mist. Some laboratories have been using a jet of steam for humidification, but this method has proven rather difficult to control.

The low humidity condition is effected by a circulation of the air in the tank through an auxiliary drying circuit. ("E," Figures Nos. 1 and 3.) A simple drying apparatus is suggested in Figure No. 7. Water cooled surfaces are used to throw out the major portion of the moisture, followed by a silica gel treatment to obtain the final drying. One-half cubic foot per minute during the entire dry period is recommended as the rate of circulation for the air. The dimensions and quantities detailed



A-LIGHT & WATER SPRAY TANK
B-PANEL SUPPORT (MOVABLE DRUM)
C-VENTILATING FINS
D-HUMIDIFYING SPRAY
E-DEHYDRATION CIRCUIT
F-LOW PRESSURE (½ LB.) LOW VOL. CENTRIFUGAL BLOWER
G-RAIN SPRAY NOZZLES
H-WET & DRY BULB THERMOMETER
I-RUBBER GASKET
J-WATER DRAIN TROUGH
K-REFRIGERATION CABINET & COOLING COILS
L-CORK INSULATION
M-LIFTING & LOWERING MECHANISM FOR PANEL RACK

FIGURE 5
Combination Exposure Unit

FIGURE 4
Combination Exposure Unit.

FIGURE 5

[illegible]

FIGURE 6
Interior of Light and Water Exposure Tank in Combination Exposure Unit.

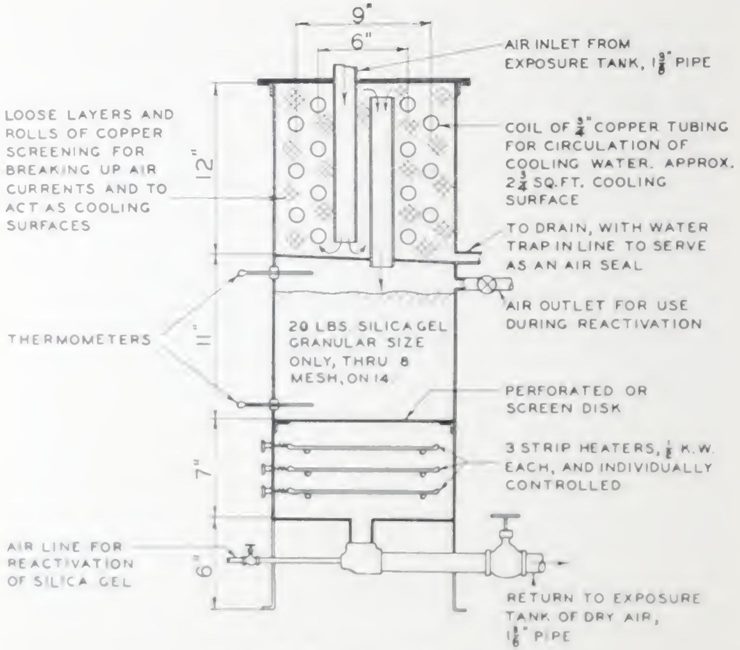


FIGURE 7—Dehydrator

in Figure No. 7 are for a dehydrater of sufficient capacity to handle the air conditioning of the large combination unit in Figure No. 3. For the smaller unit the drying apparatus can be proportionately smaller.

The operation of silica gel as a dehydrating agent is quite simple.[3] At the usual room temperatures, the gel will absorb water up to 24 per cent of its weight, and when saturated will readily give up this moisture if heated for a time by a stream of hot air. One-half a cubic foot of air per minute at about 300° F. for every ten pounds of silica gel is recommended for reactivation. Under these conditions the twenty-five pounds of spent material can be satisfactorily retreated in six hours. The reactivation process is endothermic. Thus, the temperature of the issuing air will start quite low and as the gel becomes activated will rise to about 250° F., if the incoming air is maintained at 300° F. Since it is very difficult to drive off the last traces of moisture, reducing it down

[3] E. R. Miller—"Adsorption of Silica Gel—Theory and Application," Am. Inst. Chemical Engrs. Vol. 15, Part I, Page 278, 1923.

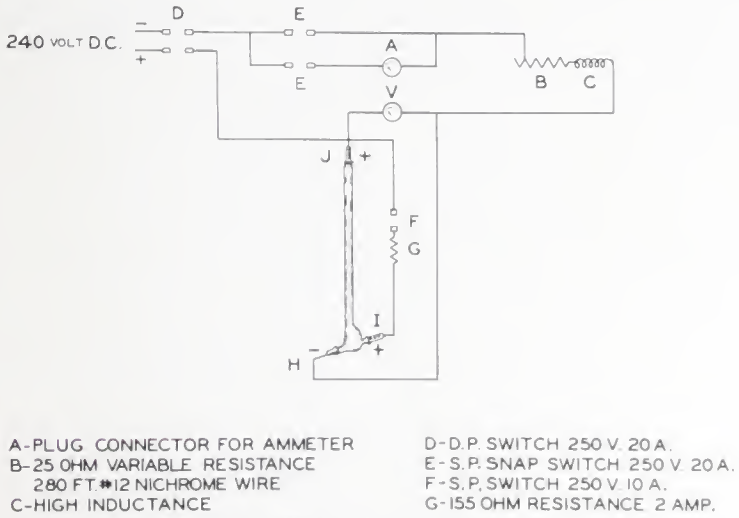


FIGURE 8

Wiring Diagram for Automatic Starting Mercury Arc Lamps—Low Pressure Type

to approximately 5 per cent by weight is sufficient for efficient operation. An additional six hours should be allowed for complete cooling of the dehydrator. With most exposure cycles, one reactivation in two to three weeks has proven sufficient. It takes about one-half hour to bring the light tank in Figure No. 3 from saturated humidity at 140° F. to less than 10 per cent relative humidity at 140° F.

Water or Rain Spray

The nozzles for the water spray exposures, simulating rain, are attached to the ventilating blades as "G," in Figures Nos. 1 and 3. It is desirable to inclose these nozzles in cone-shaped shields to prevent any back splash of the water to the surface of the mercury arc tube. Warming the spray water to about 90° F. speeds up the deteriorating action of this weathering factor, but this is not an essential procedure for satisfactory results.

Refrigeration Cabinet

As previously noted, with the single chamber unit (Figure No. 1), the refrigeration exposures are carried on in a separate cabinet. A quar-

FIGURE 9
Mercury Arc Lamps. Low Pressure Type.

the low compressor, as furnished with the larger household installations, will work quite satisfactorily. The actual exposure cabinet need be only a simple box insulated with about 3 or more inches of cork board. In the combination unit, the cooling coils of the refrigerator, whether they be a brine or a direct expansion ammonia service, are installed in the lower chamber "B," Figure No. 3. A somewhat larger compressor, about one-half ton, will be required because of the greater heat loss at the top of the cooling chamber. Any reliable manufacturer of refrigeration equipment can furnish the necessary data to determine the adaptability of his equipment.

The Destructive Light Source

The destructive light source constitutes a most important link in the test cycle. The so-called low pressure mercury lamp is used.* It is constructed of a less carefully prepared quartz material which does not have as high a transparency in the far ultra-violet as the usual clear quartz material, and thus cuts out some of the far ultra-violet not present in sunlight. The low pressure operating conditions of this lamp in-

*[illegible]

however, the principal reason that it emits less far ultra-violet than is characteristic of the high pressure Uviarcs often used for this work.

The lamps are constructed especially for accelerated weathering purposes[5] and can be obtained in ten, twenty and thirty inch lengths with an automatic starting attachment as shown in Figures Nos. 8 and 9. A slight quiver of the mercury establishes an arc between the auxiliary electrode I and H, which then jumps to J, because of the high resistance G and the inductance C. The circuit through the auxiliary electrode is then cut. These burners give 2500 to 3000 hours continuous service. Since the failure is usually due only to a clouding of the tube wall, they can be reserviced by the manufacturer at a reasonable cost.

The most satisfactory running characteristics of the lamps, when new or reserviced, are as follows:

TABLE NO. I—RUNNING CHARACTERISTICS OF NEW LAMPS

Size	*Voltage*	*Amperage*
10 inches	140	8
20 "	140	9

The wattage consumption is controlled by means of the resistances in the circuit. It is recommended that the wattage consumption be gradually increased with service, so that at the end of twelve hundred hours it will be about 20 per cent higher than the original, and thereafter kept at this higher value until the lamp is reserviced. An approximately constant total intensity can thus be maintained.

Construction Materials, Costs and Modifications

Galvanized iron and iron piping can be used, but because of the very corrosive conditions, monel metal (1/16 inch), for the light and water spray tank, and brass for the piping are recommended. Galvanized iron serves very well for the dehydrator and refrigeration cabinet lining.

It is rather difficult to make any definite estimate of cost for either the single tank or the combination units. Costs will vary depending on the labor rate, whether the job is done in the factory shops or let out on contract. Both the single tank and the combination unit have been built in our own shops using monel metal and brass as the construction materials. The single tank unit, Figure No. 1, cost approximately $600.00. This total included the mercury burner and control, silica gel dehydrator, motors, etc., but excluded the refrigeration machine and low temperature exposure box. The combination unit, Figure No. 2, cost slightly more than $2000.00. In this case, all of the auxiliary equip-

[5]By the Cooper-Hewitt Electric Company of Hoboken, N. J.

ment, including the cooling coils in the lower compartment, but excepting the actual refrigeration machine, was totalled in the cost. Since these units were built on an experimental basis, necessitating many changes in design before completely satisfactory working units were realized, the totals as given are somewhat higher than the actual cost to reproduce the units.

A low temperature exposure chamber can also be included under a unit of the size shown in Figure No. 1. The smaller size would permit some simplification of the mechanism for moving the exposure drum, and thus reduce considerably the construction cost of such a combined unit over that of the larger size shown in Figure No. 2. The overall length of such a small combined unit would not be more than four feet.

Exposure Procedure

The climatological data for Palmerton and the vicinity over a period of years has been used as the working basis for developing an accelerated exposure cycle.[6] The weathering characteristics of this accepted standard of comparison will probably hold good in a general way for a considerable portion of the United States. Research results have indicated that in the development of exposure cycles due consideration must be given to the differences in susceptibility of the materials being tested to the individual deteriorating factors of weather. Thus, for the present, it is desirable to use different cycles for various classes of materials, even though the same outdoor conditions are to be simulated.

Oleoresinous Housepaints and Varnishes for Exterior Service.

The following cycle has been giving satisfactory results when used for testing this class of materials:

	Weathering Factor	*Duration*
Monday	Refrigeration period	2½ hours
	Water spray	3½ hours
	Light—high humidity	15½ hours
	Light—low humidity	2½ hours
Tuesday	Water spray	3½ hours
	Refrigeration period	2½ hours
	Light—high humidity	15½ hours
	Light—low humidity	2½ hours
Wednesday	Refrigeration period	2½ hours
	Water spray	3½ hours
	Light—high humidity	18 hours
Thursday	Refrigeration period	2½ hours
	Water spray	3½ hours
	Light—low humidity	15½ hours
	Light—high humidity	2½ hours
Friday	Refrigeration period	2½ hours
	Water spray	3½ hours
	Light—low humidity	18 hours
Saturday	Refrigeration period	2½ hours
	Water spray	3½ hours
	Light—high humidity	18 hours
Sunday to Monday	Light—high humidity	22 hours
	Light—low humidity	2 hours
Totals	Light—high humidity	91½ hours 54.4%
	Light—low humidity	40½ hours 24.1%
	Water spray	21 hours 12.5%
	Refrigeration periods	15 hours 9.0%

The number of hours designated for each exposure period need not be absolutely adhered to, but may be varied slightly to meet individual

[6] H. A. Nelson, F. C. Schmutz and D. L. Gamble—"Accelerated Weathering: Further Development of Apparatus and Exposure Cycles," Proceedings, Am. Soc. Test. Mats., Vol. 26, Part II (1926).

working conditions. No definite observation periods are designated; these may be worked in between the changes in exposure, preferably after the low humidity-light periods. The sequence of weathering factors should be maintained as indicated, if possible.

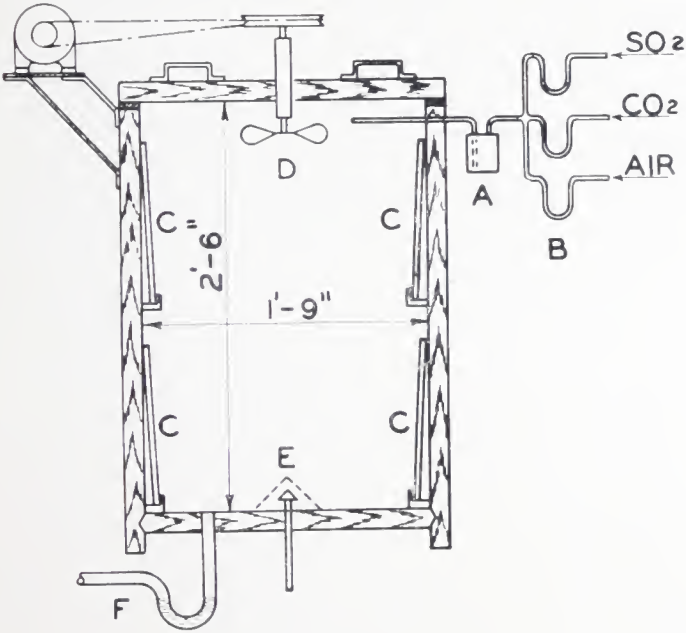
Lacquers and "Four-Hour" Enamels

After deterioration has started, materials such as lacquers and quick drying enamels are particularly susceptible to the stress and strain action of severe temperature changes. Frequent occurrence of temperature changes or refrigeration periods in the cycle may cause excessive non-representative peeling and cracking, and mask the actual durability values. Thus, for testing these materials the refrigeration periods on Tuesday and Thursday should be replaced with equivalent high humidity-light exposures, and on Saturday with a low humidity-light period.

Metal Protective Paints

If only the effects of the usual climatic conditions are to be considered, the cycle as suggested for house paints and exterior varnishes will serve very well for metal protective paints. On the other hand, since coatings of this class are so frequently used in industrial locations, it is desirable for complete information to include some gas exposure in the cycle. Based upon findings in our laboratory, covering the failure of paints in very gaseous atmospheres, the following conditions have been adopted as standard for such gas exposure periods: 80° to 100° F. saturated humidity, and an atmospheric combination of 1000 parts air, 12 parts CO_2 and 1 part SO_2. These gas exposures are for one-half hour substituted for an equivalent time of a water spray period, since the deteriorating action of industrial gases is worst upon wet or saturated films. The procedure followed is to apply one hour of water spray, one-half hour of gas, and again one hour of water spray.

As shown in Figure No. 16, the apparatus for carrying out such gas exposures consists essentially of an air tight exposure box and small gas proportioning chamber. A wooden box or covered tub of ten to twelve cubic feet volume serves very well as an exposure chamber. The air and gas mixture should be fed at a rate sufficient to change the atmosphere in the exposure box once every two to three minutes. If it is necessary to stack the test surfaces rather closely during the gas exposures, a fan should be included in the exposure box design to assure a thorough circulation of the atmosphere. A warm water atomizer, similar to that



A-GAS MIXING CHAMBER
B-GLASS FLOW METERS
C-TEST PANEL SURFACES
D-CIRCULATING FAN
E-HUMIDIFYING SPRAY & SCREEN
F-DRAIN

FIGURE 10
Gas Exposure Cabinet.

suggested for the light exposure tank in Figures Nos. 1 and 3, can be used to maintain the high humidity and elevated temperature.

Interior Finishes

Such an infinite variety of service conditions come under this designation that it is impossible to designate any one as standard. High and low humidity, water soaking due to periodic washing and scrubbing, and temperature changes here also play a part as deteriorating factors. The light, in general, is rather diffused without any appreciable amount of ultra-violet. On the basis of this analysis, we have adopted a cycle similar to that suggested for house paints, except that filtered light is used, each test panel being covered with a piece of ordinary window glass, approximately 1/8 inch thick, which will absorb most of the energy below 3300 A.U. The glass is kept one quarter inch from the test surface to permit some air circulation over the test surface.

Exposure Cycles with Oxygen Enriched Atmospheres

Since oxygen constitutes such an important factor in the natural deterioration processes, the action of the previously detailed cycles may be supplemented through the use of oxygen enriched atmospheres during all light and gas exposure periods. Outdoor failures, particularly of the checking type, are more closely simulated and the deterioration rate is further speeded up through such a procedure. On the other hand, it is not necessary to resort to this oxygen enrichment for concordant results. Durability values will be of the same relative order without it.

The normal procedure is to build up the oxygen content rapidly at the beginning of any light exposure period, and then to reduce the oxygen feed to an amount sufficient to just take care of leakage, absorption and reaction losses. For the combination unit (Figure No. 3), the oxygen feed is approximately one-half cubic foot per minute for the first ten minutes, and then one cubic foot per hour. A tank of oxygen will last a week or ten days. A gasket of plastic uncured rubber serves very effectively as a seal for the cover to prevent excessive loss of oxygen.

Preparation of Panels

The general recommendation is that all test surfaces be finished according to the system used in ordinary practice. The undercoaters have a vital bearing upon the life of the finishing coat and must receive careful consideration.

The preparation of metal panels presents no particular difficulty. Non-copper bearing black iron is recommended for testing paints used primarily for metal protection purposes, and polished sheet steel for automobile finishing lacquers. Twenty-two gauge, $\frac{1}{32}$ inch, is a desirable thickness giving sufficient thickness without excessive weight.

For tests on wood, the proper preparation of the test panel has more bearing upon the successful application of accelerated weathering as a test medium than any other one factor. Wood failures such as slitting, cupping and cracking are greatly intensified in an accelerated system. Thus, if a wood is selected which is particularly susceptible to such failures, the actual durability of the finishing materials is masked. Selected edge grain western red cedar has been found to be particularly resistant to wood failures and quite satisfactory for accelerated weathering work. The panels should be at least $\frac{3}{4}$ inch thick for a 6 x 12 inch size, and $\frac{1}{2}$ inch for the smaller sizes. Whenever flat grained material is used, the sap and not the heart side of the board should be used as the test surface. Too much emphasis cannot be placed upon the proper selection of the wood to be used.

Interpretation and Reporting of Results

The evaluation of deterioration, whether it be on outdoor or accelerated exposure, still depends mostly upon personal judgment, using such failures as chalking, checking and cracking as guides. Since visual inspection must be relied upon in the interpretation of accelerated results, due consideration must be given to the degree to which outdoor failures are actually simulated in the accelerated system. Chalking and darkening are usually worse in the accelerated system, although of the same relative order as experienced outdoors. Some laboratories resort to periodic washing of the test surfaces while under the light exposure which results in especially severe chalking. It has been found that this abnormally heavy layer of chalk is quite opaque to the destructive light and will protect the underlying film, stopping the development of further failures. Failure by cracking is more pronounced in the accelerated system than failure by checking. The failure by checking is of a very finely divided order, which is most satisfactorily observed with a low power microscope. Sub-Committee VII, Committee D-1, of the American Society for Testing Materials on Accelerated Tests has adopted[1] a 10X magnification as standard for making accelerated weathering observations. Considerable data has been obtained covering changes in gloss[2] and [illegible][3] upon weathering, but no relationship has been established between the results and durability.

A study of the climatological data on any one location over a period of years indicates a marked variation from year to year. Durability data upon similar test surfaces exposed during different years is frequently not the same, and that identical materials exposed at different seasons of the same year deteriorate quite differently. Thus, the difficulty of designating any one type of weather as standard for a location is quite evident. At best, only an average can be arrived at, which may and may not be representative of the weather for the particular year under consideration. Consequently, it is better to designate durability as determined under the accelerated systems in relative or approximate terms rather than by any fixed period of time. A comparison of outdoor and accelerated data indicates that for the system described, including the use of ozone enriched atmospheres, the acceleration of deterioration is between 12 and 15. In other words, one week in the accelerated system should represent between twelve and fifteen weeks outdoors.

[1] Report of Sub-Committee VII [illegible] of the Annual Report of Committee D-1, Proceedings, Am. Soc. Test. Mat., [illegible]

[2] [illegible] "The [illegible] and the Measurement of the Gloss of Paper," Paper Trade Journal, [illegible]

[3] [illegible] "The Measurement of [illegible]," Journal Optical Society of America, [illegible]

Actual Size Enlarged 10x

Accelerated System 70 Days.

Actual Size Enlarged 10x

Outdoor Exposure Approximately 4 Years

FIGURE 11

Comparative Failures of a Representative House Paint.

Varnishes and lacquers would more closely approach the upper figure, and house paints the lower. As previously explained, these values are, at best, only approximations. Figures Nos. 11, 12, and 13 are photographic comparisons of weathering results as obtained on the Palmerton test fence and under the accelerated system.

Since no one change induced by weathering can be accepted as a full criterion of durability, separate record must be kept of all changes, which generally involves a vast accumulation of detail data. The forms shown in Figure No. 14 have been designed to systematize the gathering of this data and to facilitate its interpretation. They have been adopted by Sub-Committee XII, Committee D-1, A. S. T. M., for its cooperative work.[9]

[9] Report of Sub-Committee XII on Accelerated Tests [illegible]

Accelerated System, Industrial Cycle—13 Days

Service Exposure—135 Days

FIGURE 12

Failures of Painted Steel Window Sash

Compare each bar in the upper photograph with the bar immediately below it.

Accelerated Exposure
[illegible] Hours

Outdoor Exposure—
Approximately a year and a quarter

[illegible] Spotted

[illegible] Spotted

Washed

Washed

[illegible]

[illegible]

Figure [illegible]

[illegible] Failure of [illegible] on [illegible] Sheet Steel

Front — Sheets for Individual Tests — Reverse

Master Sheet for Complete Series of Tests
(Only one required)

FIGURE 11
Data Sheets for Recording Observations in Detail

New Jersey
zinc

The World's Standard for Zinc Products